REMARKS

Claims 8-21 (all claims of record) have been rejected under 35 U.S.C. §103(a) alternatively as unpatentable over Kaneko (Published U.S. Patent Application No. 2002/0117126 A1), Clarke et al (U.S. Patent No. 5,117,790), or Japanese patent document JP-8028311 (Oota et al, hereinafter referred to as JP '311). However, for the reasons set forth hereinafter, Applicants respectfully submit that all claims which remain of record in this application distinguish over the cited references, whether considered separately or in combination.

The present invention is directed to a method for operating a boosted self-igniting internal combustion engine having direct fuel injection. In particular, the method according to the invention permits the operation of such an engine with stable combustion, even at lower exhaust gas temperature levels which are associated with low load and low speed range operation. That is, in known engines of this type, the temperature level in the combustion chamber falls during low speed, low load operation, making it difficult to regulate the mixture temperature, due to the smaller fuel mass involved in the combustion process.

The method according to the invention addresses and resolves this problem by providing an additional combustion air quantity and an additional fuel quantity which are introduced into the combustion chamber during an exhaust stroke of the working cycle of the internal combustion engine, after

combustion of the main mixture. The fuel-exhaust gas/air mixture formed in this manner is reacted (that is, burned) in an area of the gas exchange top of dead center of the piston. The latter combustion has the effect of raising the combustion chamber temperature prior to the main combustion taking place, in such a way as to permit regulation of the main mixture temperature. (See, for example, paragraphs [0007] and [0008] of the specification). Because the additional fuel quantity is introduced into the combustion chamber during a portion of the working cycle between the end of the piston expansion stroke and the final part of the piston exhaust stroke, the additional fuel is distributed and vaporized in a combustion chamber well before the gas exchange dead center, so that efficient combustion and heating take place. (See paragraph [0009].)

The foregoing features of the invention are recited in Claim 8, which defines a method for operating a boosted internal combustion engine in which method, during each working cycle of the engine, a main combustion air quantity and a main fuel quantity are injected into the combustion chamber forming a main mixture, which is self-ignited in an area of an ignition top of dead center during the working cycle of the engine. In addition, Claim 8 further recites that, during the same working cycle, an additional combustion air quantity and an additional fuel quantity are introduced into the combustion chamber during an exhaust stroke of the working cycle, after combustion of the main mixture, such that a fuel-exhaust gas/air mixture is formed. The latter mixture is then reacted

in the vicinity of a gas exchange top of dead center (at the completion of the exhaust stroke) of the piston.

Accordingly, the method according to the invention includes the following features:

- The additional fuel quantity is introduced into the combustion chamber during the exhaust stroke of the working cycle of the engine, after the combustion of the main mixture; and

- The fuel-exhaust gas/air mixture is reacted near the gas exchange top of dead center (that is, the top of dead center which follows the exhaust stroke, as distinct from the ignition top of dead center which follows the compression stroke, and immediately precedes combustion of the main mixture); and

- The main mixture is self-ignited by the prevailing pressure in the area of the ignition top of dead center.

According to a further feature of the invention, as recited in Claim 4, at least one exhaust valve of the combustion chamber are opened during the introduction of the additional fuel quantity.

The latter features of the invention are not taught or suggested by the cited references.

Kaneko, for example, discloses a combustion control apparatus for an engine having a variable valve timing mechanism, such that the engine can be operated in any of three modes, including a four-cycle compression ignition combustion mode at a low and medium load, a two-cycle spark ignition combustion mode at a high load area, and a four-cycle spark ignition combustion load at a high speed area. The Office Action indicates that the features of independent Claim 8 are disclosed in Figure 4b of Kaneko, which illustrates the engine operating in a two-cycle mode, as described in paragraph [0040] of the specification. Applicants note in this regard, however, that, unlike Figures 4a and 4c, which illustrate separate exhaust, intake compression and expansion strokes, which collectively form a single operating or working cycle of the engine, Figure 4b illustrates two working cycles of a two-cycle engine, each working cycle comprising a compression stroke and an expansion/exhaust stroke, which is typical of two-cycle engines. Accordingly, during each operating cycle (compression stroke plus expansion/exhaust stroke), there is but a single injection. Accordingly, Kaneko does not teach or suggest an operating method in which both a main fuel quantity and an additional fuel quantity are injected during a single working cycle of the engine, as recited in Claim 8, for example.

Moreover, Claim 8, as amended, also recites that the additional fuel quantity is injected into the combustion chamber "during an exhaust stroke of said working cycle, after the combustion of the main mixture". However, as can be clearly seen from Figure 4b of Kaneko, the single fuel injection which occurs during each working cycle of the engine takes place during the compression stroke. In this regard, Applicants note that paragraph [0040] of the specification in Kaneko states that, the combustion gas is discharged through the exhaust valve 7 in the latter half of the expansion and exhaust stroke, after which the intake valve 6 opens to supply "fresh gas (boosted by the supercharger 30) to the combustion chamber 3". It is apparent that the latter reference to the supercharger 30, refers to the injection of pressurized air into the combustion chamber, since the fuel is injected via fuel injector 11, not through the supercharger 30.

Therefore, the Kaneko reference differs from the present invention in that only a single fuel injection occurs in each working cycle of the engine. Moreover, the single fuel injection takes place during the compression stroke, and not during the exhaust stroke of the working cycle as recited in Claim 8.

In addition, since Kaneko does not include an additional fuel injection corresponding to that of Claim 8, it also follows that it does not provide for the reaction of a resulting fuel-exhaust gas/air mixture "in an area of a gas exchange top of dead center of the piston".

Finally, Claim 8 as amended further recites that the main mixture of fuel and air is caused to self ignite by prevailing pressure in the area of the ignition top of dead center. This feature, which is disclosed in the specification at paragraph [0018] (substitute specification), lines 6-8, is also neither taught nor suggested by the cited references, in a system that includes an additional fuel injection such as defined in Claim 8.

Accordingly, Applicants respectfully submit that Claim 8, and therefore all claims which remain of record in this application distinguish over Kaneko.

The Clarke et al reference is similar to Kaneko, disclosing a system for controlling operational modes of an engine as between eleven different variations as illustrated in Figure 4 and discussed in the specification at Column 6, line 1 through Column 7, line 2.

The Office Action refers in particular to the Abstract of Clarke et al, as well as the "early intake closing 2-stroke" operating mode illustrated in Figure 4 as anticipating Claims 8-21. Applicants note in this regard, however, that like Kaneko et al, the "early intake closing 2-stroke" operating mode illustrated in the next to the bottom line in Figure 4 is used to depict both 2-cycle and 4-cycle operation. In 4-cycle operation, of course, there are four different "strokes", including an intake stroke, a compression stroke, an expansion stroke, and an exhaust stroke, as discussed, for example, at Column 6, lines 6 through 11.

However, in case of 2-cycle operation, the operating cycle consists of only two strokes (for example as discussed above with regard to Kaneko et al) being a compression stroke and an expansion/exhaust stroke, which together form a whole operating cycle. Accordingly, as can be seen from the right-hand column in Figure 4, the diagram for "early intake closing 2-stroke" operation illustrates two operating cycles of a 2-cycle engine, each of which includes a single fuel injection which occurs just prior to the expansion/exhaust stroke, at the latter portion of the compression stroke. Accordingly, like Kaneko et al, Clarke et al fails to teach or suggest a method of operation such as defined in Claim 8, in which, during each working cycle of the engine, both a main fuel quantity and an additional fuel quantity are injected into the combustion chamber. Moreover, it fails also to teach or suggest a method of operation in which the additional fuel quantity is injected during an exhaust gas stroke of the working cycle, forming a fuel-exhaust gas/air mixture that is reacted "in an area of a gas exchange top of dead center of the piston".

Finally, JP '311 discloses a control device which controls the operation of a 4-cycle engine in such a manner as to reduce discharge rates for hydrocarbons and nitrogen oxides during cold operation. For this purpose, as indicated in the Abstract of the Disclosure, gas circulation valves 32a and 32b are provided, which are opened during an initial period of the exhaust process during cold operation, for circulating the combustion gas to intake ports 5a, 5b. As also

noted in the specification, the combusted gas circulation valve also serves as an intake valve 31.

The Office Action refers to the Abstract of the Disclosure and to Figure 15 as anticipating Claims 8 through 21. However, the Abstract of the Disclosure itself appears to contain no discussion of fuel injection into the combustion chamber, and in particular no discussion which suggests the provision of an additional fuel injection quantity, such as recited in Claim 8.

Figure 15, on the other hand, includes a graph which arguably shows first and second fuel injections, based on handwritten notations which appear on the copy provided with the Office Action. Without a translation, Applicants are unable to affirm whether the top line in fact shows first time and second time fuel injections, as suggested. Nevertheless, accepting these designations as accurate for the purpose of discussion, Applicants have been able to find nothing either in Figure 15 or in the English-language Abstract which teaches or suggests that an additional combustion air quantity and an additional fuel quantity are injected into the combustion chamber "during an exhaust stroke" of the working cycle of the engine, or that a fuel exhaust gas/air mixture which is formed as a result is in fact reacted in an area of a gas exchange top of dead center of the piston. The latter limitations are a significant feature of the present invention, in that they permit the injection of an additional fuel quantity to occur just prior to the time when the piston reaches the gas exchange top of

dead center, so that the resulting mixture can be reacted at that time, raising the temperature within the combustion chamber and thereby achieving the additional degree of stability referred to previously. Applicants respectfully submit that the latter features of the invention are not taught or suggested by JP '311.

In light of the foregoing remarks, this application should be in consideration for allowance, and early passage of this case to issue is respectfully requested. If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #095309.56087US).

Respectfully submitted,

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